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Opto Semiconductors

Using visible InGaN laser diodes from OSRAM Opto Semiconductors

Application Note

Valid for:
InGaN visible laser diodes

Abstract

OSRAM Opto Semiconductors offers visible, InGaN-based laser diodes that are well suited for automotive and industry applications, as well as for projection. This application note provides a guideline for the proper use of visible InGaN laser diodes from OSRAM Opto Semiconductors and describes their technical details as well as the operation of the laser diodes.

Further information:
For more detailed information and the latest product update visit www.osram.com/os and the OSRAM Opto Semiconductors LED Information Base or contact your local sales office to get technical assistance during the design-in phase.

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A. Basic information on handling and assembly

Safety instructions

Depending on the mode of operation, laser diodes (refer to Figure 1) emit highly concentrated visible light which can be hazardous to the human eye. Products which incorporate these devices must follow the safety precautions specified in IEC 60825-1 "Safety of laser products".

Figure 1: Product picture of a green single-mode laser (PL 520 in a TO38icut package)

PL 520

Testing and maintenance of these products shall be only performed by personnel trained in laser safety. For more details please refer to the relevant local safety regulations and the requirements for manufacturers specified in IEC 60825-1.

The manufacturer of the final product must determine the laser class based on the driving conditions and the optical design, such as focusing lenses.

Storage and shipping

Storage and shipping should be done in a clean and dry atmosphere in a certain temperature range. Please refer to the “Storage Temperature” range in the data sheet.

Unpacking and handling

The visible InGaN diode lasers are shipped in a conductive plastic shipping container that is packed in a sealed conductive plastic bag.

Before opening the plastic bag, diode lasers should be kept at room temperature (in the room where the bag will be opened) for at least 4 hours to achieve thermal equilibrium. The protective bag may be opened only in a clean environment and non-humid atmosphere.

Solvents, non-conductive plastics and glues are not allowed near the diode lasers, because solvents could emerge and deposit on the window. Especially, the blue multi-mode power laser light can bake the contamination on the window, reducing its transparency.

Dust on the window can be removed by cleaning with oil-free compressed air. Mechanical stress to the window should be avoided in order to prevent the breaking of the hermetic seal.

Please also avoid scratches to the bottom surface of the TO package. These can increase the thermal resistance of the device mounted to the heat sink, which might result in reduced efficiency and thermal overload of the diode laser.

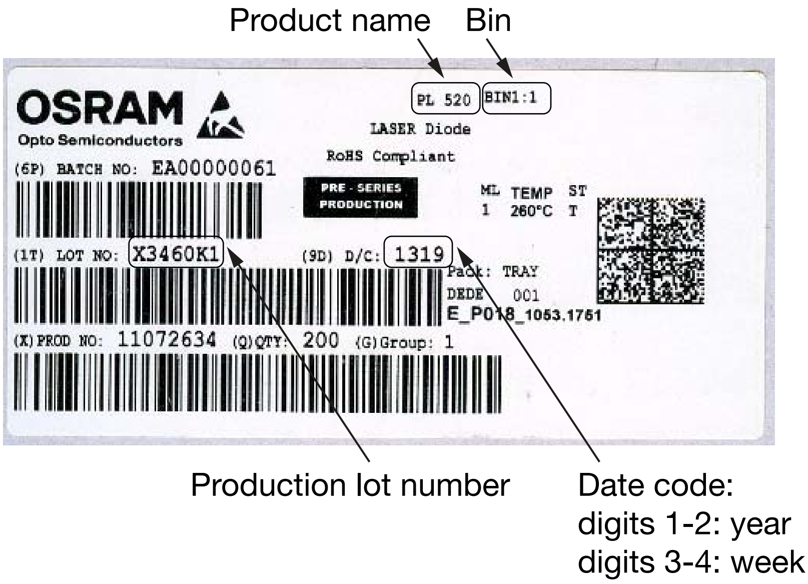
Operation in a particle-free and sealed environment is recommended as due to the high luminance, particles on the window of the TO package can lead to local heating of and damage to the window. Moreover, a sealed environment can prevent the steel cap of the TO package from aggressive impacts such as corrosion through interaction with salt.

Mechanical stress on the pins or bending of the pins can lead to damage to the hermetic seal and has a negative effect on long-term stability.

Label information

Figure 2 shows the label for visible laser diodes is which is placed on the sealed conductive plastic bag. The date code reflecting the Backend production date is printed on the label in addition to the product name, binning information and the production lot number.

Figure 2: Standard label for visible laser diodes



ESD handling

Since InGaN diode lasers are electrostatic sensitive devices, their handling requires strict precautions against electrostatic charges. Every person and each tool that might get into contact with the diode laser must be continuously ESD-protected. Therefore, the devices should only be handled in ESD-protected areas (EN 100 015 former CECC 000 15).

InGaN laser diodes without an ESD protection diode have an ESD class 0 according to the Human Body Model. ESD pulses in reverse voltage in particular can cause damage to the laser diodes. Operating the laser afterwards may result in a strong reduction of output power.

Recommendations for ESD control. To enhance the protection grade in the laser module we recommend implementing an ESD protection diode (e.g. Zener Diode) in the circuit design, if there is no ESD diode in the laser package already. The following points must be considered in order to ensure the proper protection of the diode:

- Breakdown voltage: The breakdown voltage of the ESD protection diode must be higher than the total forward voltage of the laser diode in order to ensure the correct functioning of the circuitry under normal circumstances.

- Response time: The response time of the ESD protection diode must be faster than that of the laser diode. Thereby, the protection mechanism can work effectively before a pulse may cause any damage to the laser diodes. Due to the fast switching times of the laser diodes, the response time of the protection diode is supposed to be in the range of 1 ns or less.

Basics for protection against static:

Grounding. Grounding systems shall be used to ensure that devices, personnel and any other conductors are at the same electrical potential.

Protection. To avoid exposure to static charges, keep components and modules separated during storage and transit. Through protection against statically charged objects and electric fields potential damage to laser components is minimized.

As statically charged insulators cannot be discharged by grounding, it is advisable to eliminate non-conductive plastic materials and other types of insulators from the working place, transit and storage areas.

Neutralization. Neutralization is the process to discharge insulators. This happens naturally through the process of ionization. Ions are charged particles that are always present in the atmosphere in the form of atoms, molecules or groups of molecules such as drops of water. The use of an ionizer generates billions of ions in the air and enables the static charge on an insulator to leak away.

Prevention. Prevention can be the most effective and important personal contribution to eliminate damage caused by ESD. Please find a set of guidelines below:

- Always keep working areas clean and tidy. Remove unwanted objects, especially those made of non-conductive plastic materials.
- When transferring components from one person to another, both persons should be grounded or at the same voltage potential.
- Avoid laser components or modules coming into contact with any insulating material.
- Never enter a static-proof working area without taking the necessary precautions.
- Always be aware of these rules when working with devices that can be damaged by electrostatic discharges.

For further information on ESD handling please refer to the application note "ESD Protection while Handling LEDs" which also applies to InGaN laser diodes.

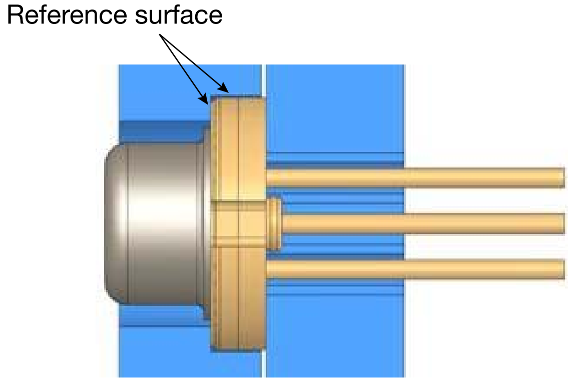
B. Mounting and thermal management

Mounting

A laser diode should only be mounted at the baseplate of the TO package. The cap should not be exposed to mechanical stress.

The reference surface for positioning the laser diode is the front side and the circumference of the baseplate, see Figure 3.

Figure 3: Reference surfaces of a TO56 package



To prevent breakage of the hermetic seal of the pins, the laser diode's pins and baseplate must not be exposed to mechanical stress during mounting. Deformation of the baseplate must be avoided.

Thermal management

Appropriate cooling is required in order to obtain the specified output power and a long lifetime of the laser diode. The maximum rating for the junction temperature $T_{Junction}$ for GaN lasers is 150 °C. Operation at this value will reduce significantly the lifetime of the diode. For long term operation the junction temperature should not exceed 100 ° C.

The junction temperature can be calculated using the following equation:

$$T_{Junction} = (U \cdot I - P_{opt}) \cdot R_{th} + T_{Case}$$

,where P_{opt} is the optical output power, U the operating voltage, I the operating current, T_{Case} the temperature of the package and R_{th} the thermal resistance (junction to case). For further information on thermal management refer to the application note: "Package-related thermal resistance of LEDs".

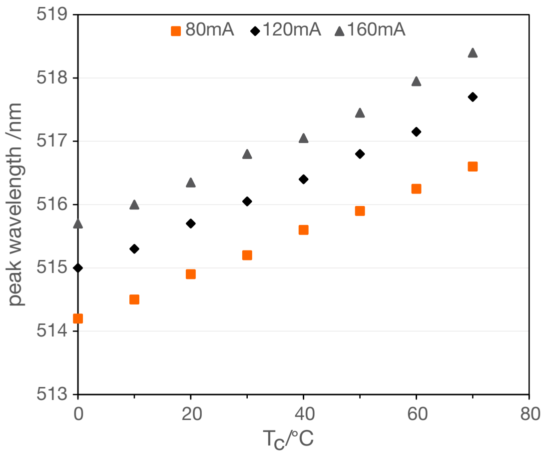
Insufficient cooling can also result in a significant reduction of the output power, especially at high power levels or temperatures. In the worst case the output power can even drop to zero within the specified operating range.

If a laser diode does not reach the specified optical output power at the specified maximum operating current, please review your cooling system.

Wavelength shift versus temperature and current

The shift of the emission wavelength with temperature for GaN laser diodes is in the 0.04 to 0.06 nm/K range. Figure 4 shows the wavelength shift for the PL_520 at various currents and case temperatures.

Figure 4: Influence of the cooling on the peak wavelength of the PL_520.



Thermal rollover

A so called thermal rollover in continuous wave (cw) operation is observed mainly for the visible multi-mode lasers which have the highest thermal load at the operating point. This effect is caused by self-heating of the laser diodes. The rollover starts at lower currents with increasing temperature due to lower efficiencies at higher temperature.

If a laser diode is operated in overstress, which means at too high power levels or temperatures and therefore, driven close to or at this thermal rollover the lifetime of the laser diode will be reduced.

C. Electrical and optical considerations

Visible InGaN laser diodes from OSRAM Opto Semiconductors are developed for cw operation. To obtain the full lifetime it is strongly recommended not to exceed the nominal output power and the nominal operating conditions (operating current, case temperature) for a longer period of time. Operation above nominal conditions may reduce the lifetime of the laser diode and operation above the maximum ratings specified in the data sheet even for a short time may irreversibly damage the device.

Visible InGaN laser diodes from OSRAM Opto Semiconductors may also be operated in pulsed mode at any pulse widths between a few nanoseconds and cw operation and at any duty cycle. However, the maximum ratings specified for cw operation also apply to the pulsed operation.

Furthermore, please note that the output power of the laser diode depends on the temperature. Thus, for applications that require constant output power over a broad range of temperatures, an automated power control (APC) is required. A photodiode (PD) is usually adopted to optically monitor the output power of the laser diode. OSRAM Opto Semiconductors provides a series of photo detectors with compact size and high sensitivity which are suitable for APC (refer to the Appendix, Table 1).

Operating conditions

As a semiconductor laser is inherently a current-driven device, a true current source is recommended for driving laser diodes.

Laser diodes must not be driven by a voltage source. Similar to LEDs, the forward voltage depends on the junction temperature and differs from device to device.

An ideal power supply for a laser diode has the following characteristics:

- Current source
- Transient suppression (also low noise)
- Independent clamping current limit
- Slow start / ramping the current signal during switch-on
- Output overvoltage protection
- Input undervoltage detection
- Output short-circuit / interruption detection
- Shorting output during driver off status for ESD protection
- No undershooting of the output voltage at switch-off of the laser, so that a negative voltage over the laser diode cannot occur.

As a laser diode has a very short rise time and the mirrors of the resonator are the most sensitive parts of the design, even short current peaks beyond the maximum data sheet conditions may lead to a catastrophic optical mirror damage (COMD) resulting in a significant reduction of optical output power. Especially when switching the laser diode on and off, transient currents beyond the maximum conditions can occur which must be blocked.

For this reason, the maximum conditions for current and optical output power given in the data sheet must not be exceeded, not even in pulse mode.

Mains supply circuits should be designed to block external noise sources such as inductive loads. Battery-driven designs are more relaxed in this regard. External in-coupling of noise can be reduced by a circuit design with short connection paths between the laser driver and laser diode.

Laser diodes shall be driven with a regulated driver, so either in constant current mode (ACC Automatic Current Control) or constant optical power mode (APC Automatic Power Control). For APC control a photo diode is used to feed back the optical output power detected in order to control the laser diode current to maintaining constant optical output power.

To protect against turn-on transients, a laser diode driver should feature a slow-start circuit at switch on. The slope of the turn on ramp should be applied according to the application needs.

Moreover, there is a need to limit the output current. Otherwise damage to the mirror facet may result.

A separate overvoltage protection of the power supply ensures that the output voltage is limited in terms of changes of impedance of the load, e.g. interruption of the load connection.

An input undervoltage detection ensures the proper control of the constant current regulator to start working after the full input voltage is applied.

Ideal laser diode drivers offer a shorting feature to maintain the output leads at the same electrical potential when the laser is not being operated. This shorting output feature offers ideal ESD protection during off status.

When switching off the laser diode an undershooting of the output voltage is not allowed as the laser diode is not designed for application of reverse voltages.

Most integrated driver solutions provide the above-mentioned safety features and only require a few additional external parts.

Especially for a cold start, the temperature dependency of the forward voltage of the laser diode has an influence on the switch-on behavior of the laser diode driver.

OSRAM Opto Semiconductors recommendation: The lifetime of the laser diode should be validated in an appropriate lifetime test at customer side for the driver design used.

OSRAM Opto Semiconductors cannot be held liable for the completeness of the recommendations. The customer must perform his own tests to verify the design.

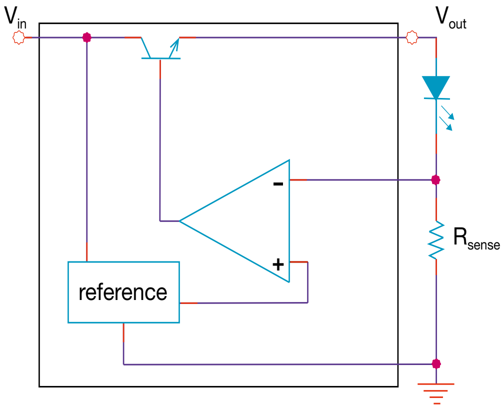
There are 2 main driver topologies for constant current drivers:

- Linear regulator
- Switching regulator

Linear regulator

Described simply, a linear regulator consists of 3 parts as shown in Figure 5: a reference voltage, a transistor/MOSFET and an amplifier for feedback control of the sense signal. A linear regulator controls a pre-defined output voltage or current.

Figure 5: Simple schematic of a linear regulator with an NPN-transistor and a sense resistor for feedback to control constant current



With a linear regulator, the input voltage must be higher than the output voltage plus a minimum voltage for the transistor/MOSFET in order to be able to regulate the target output current. The dropout voltage is defined as the difference between input and output voltage, where a further reduction of the input voltage would result in not being able to control the target current on the output. This voltage, which is needed at minimum, is specified in the respective data sheet of the laser diode driver.

The power loss P_d of a linear regulator is mainly given by:

$$P_d = (V_{in} - V_{out}) \cdot I_{out} + V_{in} \cdot I_q$$

,where V_{in} is the input voltage, V_{out} the output voltage, I_{out} the output current and I_q the quiescent current.

Due to production-based variations and the temperature dependency of the forward voltage of the laser diode, the V_{in} for the laser driver must be set with a certain safety margin above the V_{out} required.

Switching regulator

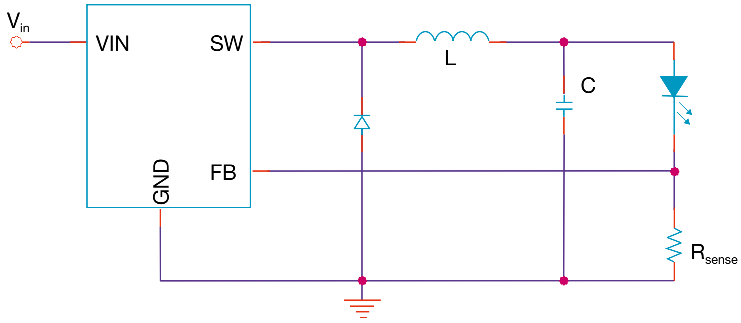
With a switching regulator, the electrical power from the input side is converted to the output side at a different voltage/current level. The input voltage can also be lower than the output voltage.

Examples of different topologies:

- Buck (set down converter, output voltage lower than input voltage)
- Boost (set up converter, output voltage greater than input voltage)
- …

Figure 6 shows a simple schematic of a buck topology with controller, internal MOSFET and sense resistor for current control feedback.

Figure 6: Simple schematic of a buck topology with controller and a sense resistor for feedback to control constant current



The buck controller switches the input voltage V_{in} with a certain duty cycle to the output pin SW. The inductor current results as integral of the inductor voltage $u_L(t)$ according to

$$u_L(t) = L \cdot \frac{di_L(t)}{dt}$$

thus resulting in a triangle-shaped current form.

The diode acts as a recovery diode during switch-off status on output pin SW. The capacitor acts as a voltage source during switch-off status on output pin SW and smoothens the current signal on the load side. The signal on the sense resistor is used to control the duty cycle of the buck controller to a target output current.

The power losses of a switching regulator are mainly given by:

- Conduction losses during switch on phase:

  $$P_{on} = R_{DS_{on}} \cdot I_{out}^2 \cdot D$$

  , where $R_{DS,on}$ is the drain-source on-state resistance, I_{out} the output current and D the duty cycle.

- Switching losses:

  $$P_{SW} = V_{in} \cdot I_{out} \cdot (T_{rise} + T_{fall}) \cdot \frac{1}{2} \cdot f_{SW}$$

  , where V_{in} is the input voltage, I_{out} the output current, T_{rise} the rise time, T_{fall} the fall time of the MOSFET and f_{SW} the switching frequency of the MOSFET.

- Quiescent power losses:

  $$P_q = V_{in} \cdot I_q$$

  , where V_{in} is the input voltage and I_q the quiescent current.

If a pure switching regulator is to be used for a constant current source, the design must be performed to ensure all the requirements for a laser driver mentioned under “operating conditions”. There are many integrated circuit (IC) manufacturers who provide e.g. buck or boost controller.

Low power driver solutions

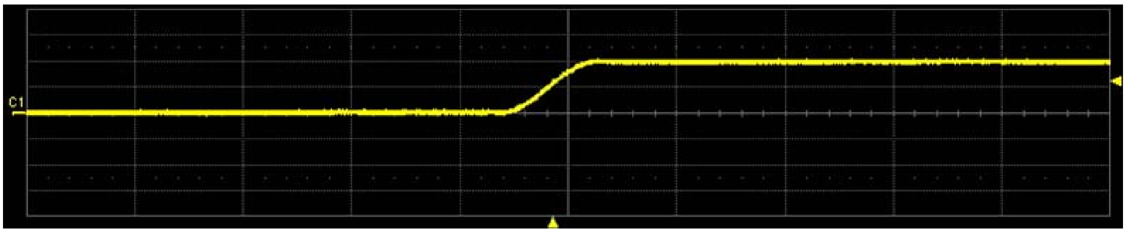
For low power applications, the most common driver topology is the linear regulator, as the absolute power losses are relatively low and the requirements for a laser diode driver as mentioned in the "Operating conditions" chapter are easier to fulfill compared to a pure switching regulator.

For example, the laser diode driver iC-NZN (www.ichaus.de/ic-nzn) from the manufacturer iC-Haus GmbH allows CW operation and switching with defined current pulses up to 155 MHz in controlled burst mode with currents up to 300 mA. "Controlled" means that a pre-set operating point is maintained during the burst phase via the LVDS/TTL switching input. The driver enables both APC and ACC mode with the setting of an external resistor. It features a laser current limitation, a fast soft-start function and strong transient suppression with small external capacitors.

Figure 7 shows an example of the soft-start current feature after switch on of the laser diode driver iC-NZN to ramp up to 100 mA without any transients beyond maximum conditions.

Please check the manufacturer's webpage (www.ichaus.de) and their support contact for further documentation or technical support on their offered laser drivers.

Figure 7: Example of a soft-start feature of a laser diode driver to an output current of 100 mA without transients at switch on



Optical

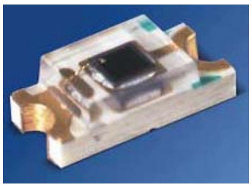
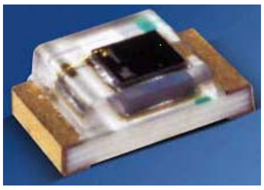
In case of optic design or simulation needs, ray files of laser diodes for various software versions (e.g. Lighttools, Zemax, ASAP, Tracepro, Speos) can be downloaded from the OSRAM Opto Semiconductors web site (Application Support): www.osram.com/os/

For latest updates regarding available secondary lenses, please contact your local OSRAM Opto Semiconductors sales office.

D. Appendix

Selected photo detectors available for APC (www.osram.com/os/)

Table 1: Series of compact-size and high sensitivity photo detectors from OSRAM Opto Semiconductors which are suitable for the APC feature

Part number	Picture	Spectrum range	Package size
SFH2701		400~1050 nm	$1.5 * 3.2 * 1.1\ mm^3$
SFH2430		400~900 nm	$4.4 * 3.85 * 1.15\ mm^3$
SFH3711		440~690 nm	$2 * 1.28 * 0.8\ mm^3$
SFH3204		420~1100 nm	$1.1 * 3.0 * 1.2\ mm^3$

Don't forget: LED Light for you is your place to be whenever you are looking for information or worldwide partners for your LED Lighting project.

www.ledlightforyou.com

ABOUT OSRAM OPTO SEMICONDUCTORS

OSRAM, Munich, Germany is one of the two leading light manufacturers in the world. Its subsidiary, OSRAM Opto Semiconductors GmbH in Regensburg (Germany), offers its customers solutions based on semiconductor technology for lighting, sensor and visualization applications. OSRAM Opto Semiconductors has production sites in Regensburg (Germany), Penang (Malaysia) and Wuxi (China). Its headquarters for North America is in Sunnyvale (USA), and for Asia in Hong Kong. OSRAM Opto Semiconductors also has sales offices throughout the world. For more information go to www.osram-os.com.

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